United States
Environmental Protection
Agency

EPA/540/F-93/509
August 1993

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Emerging Technology Bulletin

Removal of Phenol from Aqueous Solutions Using High Energy Electron Beam Irradiation

Florida International University and the University of Miami

Technology Description

Irradiation of aqueous solutions with high-energy electrons results in the formation of the aqueous electron, e^-_{aq}, hydrogen radical, H·, and the hydroxyl radical, OH·. These reactive transient species initiate chemical reactions capable of destroying organic compounds in aqueous solution, in most cases oxidizing them to carbon dioxide, water and salt. No sludge is formed and no pretreatment is necessary. The reaction by-products are nontoxic and thus this process represents a new technology for the restoration of contaminated water, soils and sediments.

At one end of the system, an aqueous solution containing the hazardous organic chemical(s) is directed over a weir where it falls in a thin sheet (approximately 4 millimeters thick). At the other end of the system, a 1.5-million volt insulated core transformer (ICT) electron accelerator generates electrons and accelerates them to approximately 97% the speed of light. These accelerated electrons are propelled in a concentrated beam down a high-vacuum tube toward a scanner which scans the beam to a rectangular shape and directs it toward the aqueous solution which is flowing over the weir. It is at this point, when the electrons penetrate the waste stream, that treatment occurs. The studies have been conducted at 120 gal/min, and can be easily scaled up for larger applications. The process is essentially pH independent in the range 3-11.

Waste Applicability

Current studies using high energy electron beam irradiation have demonstrated that the process is efficient for the destruction of several classes of hazardous organic compounds. These studies have been extended to the destruction of phenol in aqueous solution in a large-scale flow-through system. Studies were conducted at solute concentrations of 1, 10 and 50 mg L^{-1}, over the pH range 5-9, in the presence and absence of 3% w/w kaolin clay.

Test Results

High energy electron beam irradiation effectively removes phenol from aqueous solutions at large scale. Removal is affected by solute concentration, absorbed dose and total alkalinity. Other water quality parameters such as the presence of suspended solids and solution pH are not important factors influencing compound removal. At high phenol concentration (≈950 μM), recircu-

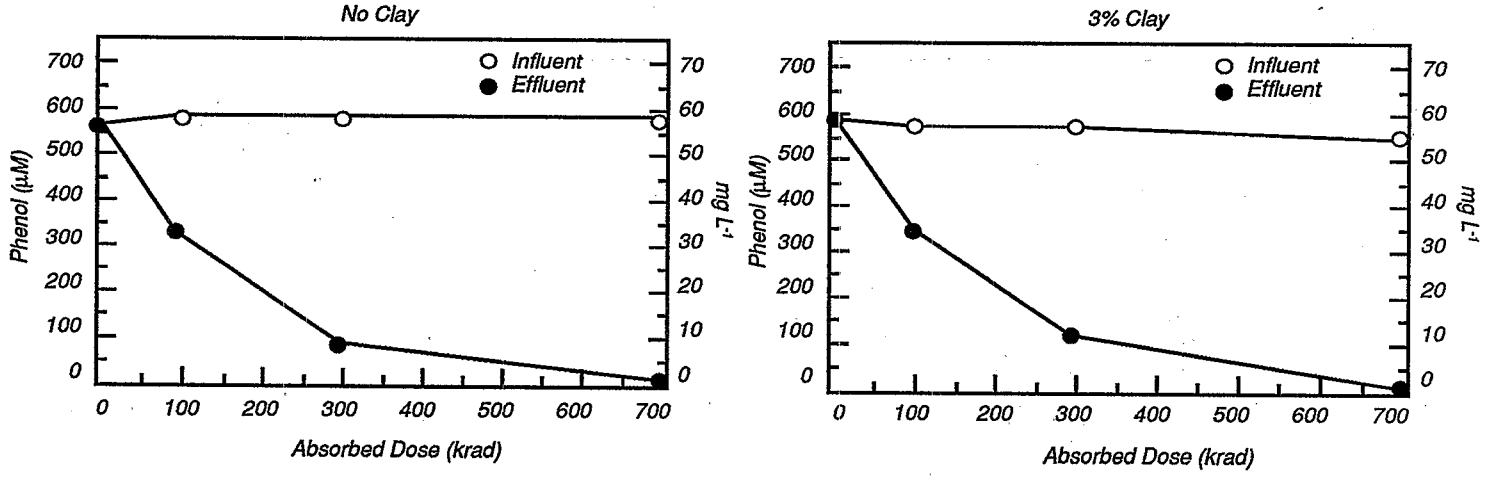

Figure 1. *Removal of phenol in the presence and absence of inert solids (3% clay) using the electron beam treatment process.*

lation of the waste stream was necessary to destroy all of the phenol and its reaction by-products.

It was shown that high energy electron beam irradiation leads to the formation of oxidized reaction by-products. At low doses and low phenol concentrations, more than 50% of the decomposition of phenol was attributed to the formation of hydroquinone, catechol and trace amounts of resorcinol. The formation of these dihydroxy phenol derivatives correspond closely to those reported as reaction by-products of phenol with OH· radicals. In addition, aldehydes and formic acid were also identified as reaction by-products.

For Further Information:

Franklin Alvarez, EPA Project Manager
Risk Reduction Engineering Laboratory
USEPA
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7631
Fax (513) 569-7620

Technology Developer Contact:

William J. Cooper
Drinking Water Research Center
Florida International University
Miami, FL 33199
(305) 348-3049
FAX (305) 348-3894

Charles N. Kurucz
Department of Management Science and Industrial Engineering
University of Miami
Coral Gables, FL 33134
(305) 284-6595
FAX (305) 284-2321

Thomas D. Waite
High Voltage Environmental Applications, Inc.
9562 Doral Boulevard
Miami, FL 33178
(305) 593-5330
(305) 533-0071 (FAX)

*U.S. Government Printing Office: 1993 — 750-071/80058

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use
$300

EPA/540/F-93/509

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35